Exhaustion

A Guide to Transportation Emissions

Environment Canada Environnement Canada

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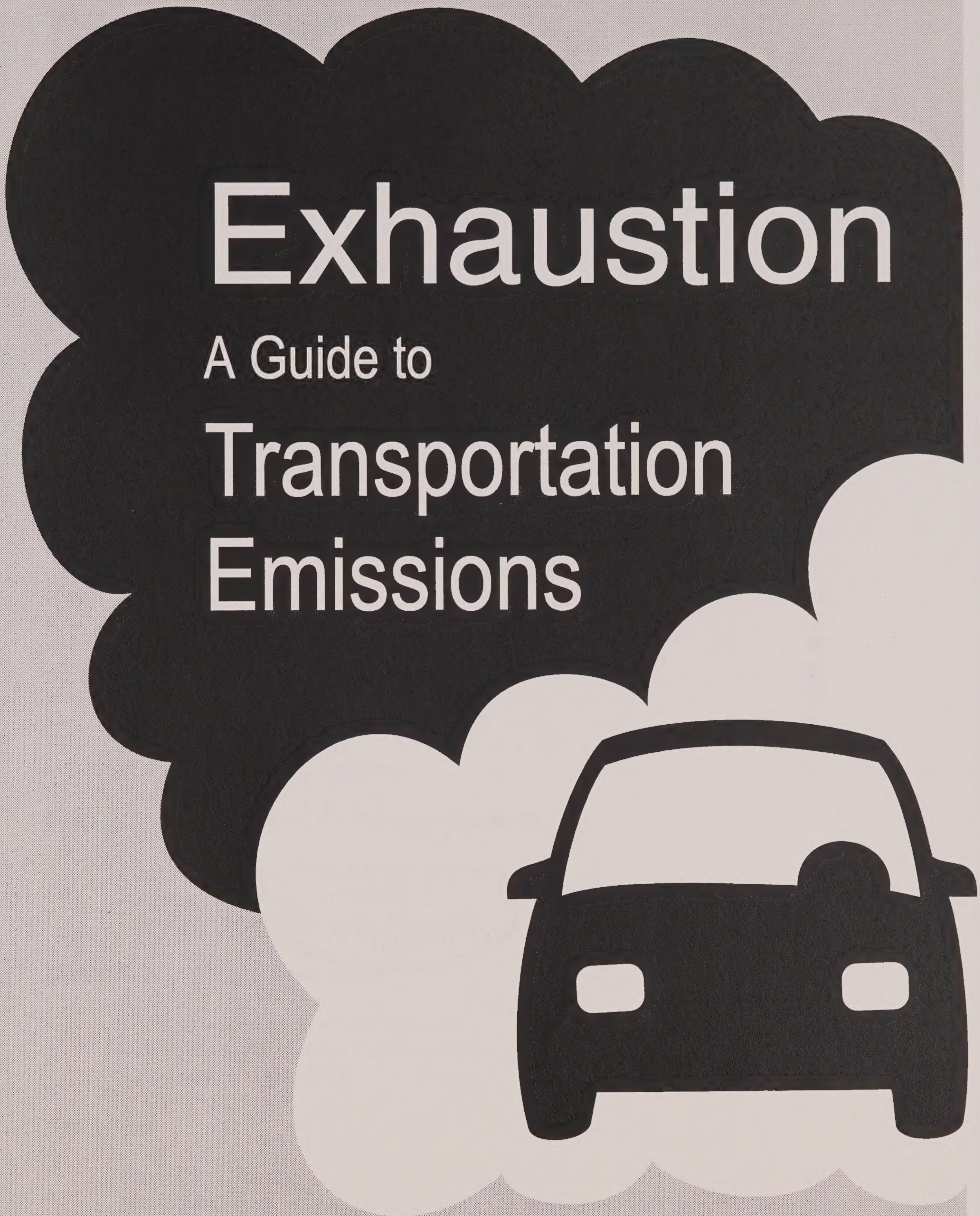

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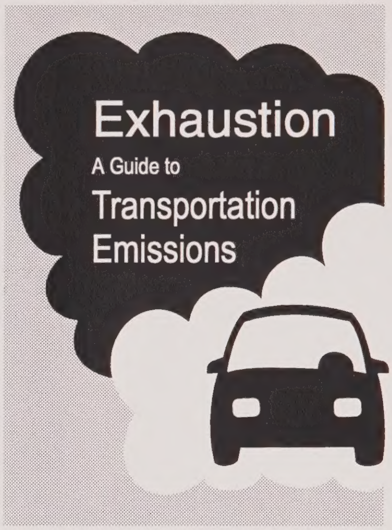
1 Section One
Setting the Context

Why this Publication

Cars have a profound and pervasive impact on the environment, and no single solution will solve the air pollution and traffic problems created by our use of the automobile. The issues are not simple, the science involved can be confusing, and changes in technology are so rapid it can be a challenge to keep up. Understanding the impact of the automobile on the environment and human health is the key to making important choices for a more environmentally friendly automobile and a sustainable transportation system.



This publication contains a series of fact sheets on the environmental impacts of the automobile; they address the issues of vehicle exhaust and its impact, alternative and cleaner fuels, and alternative forms of transportation. These fact sheets are intended to serve as background information and reference material.

Introduction

Issue:

Although the introduction of the automobile into society brought personal mobility and access to economic opportunities, these benefits must be weighed carefully against the associated environmental and health impacts.

Cars in Canada

The car is prominent in our society because of our desires for mobility, flexibility, independence and status. Urban and suburban development patterns have been increasingly influenced by the automobile. At the same time, this development has promoted the use of the car and has made Canadians dependent on the automobile. This dependence has an environmental cost. Most Canadian cities sit on land that was once prime farmland. Natural ecosystems have been paved over or disrupted by roads. And cars and their supporting infrastructure consume large quantities of non-renewable resources such as oil, gas, and metals; and lead to the creation of a vast array of toxic synthetic compounds. The operation of motor vehicles releases pollutants such as NO_x, VOC, CO, and particulate matter, as well as greenhouse gases such as CO_2.

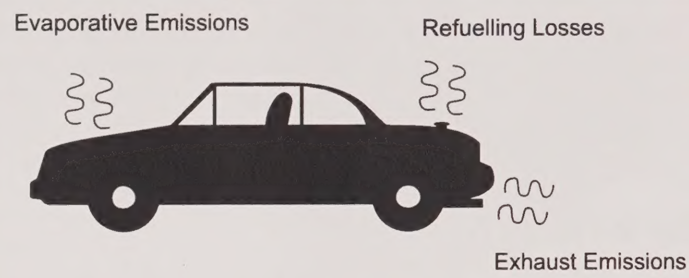
Car sales mirror the economy. As the economy improves, so do motor vehicle sales; as it slows, sales slow down as well. Approximately 1.9 million motor vehicles are produced each year in Canada. Today, more than 17 million vehicles travel Canadian roads, which means one car for nearly every two Canadians. Each car travels, on average, 16,000 kilometres per year, for an annual total of over 200 billion kilometres. There are over 879,000 kilometres of highway in Canada. In places, up to 42 percent of urban space has been consumed by motor vehicle infrastructure.

While cars are becoming lighter, more fuel-efficient and less polluting, the ever-increasing number of vehicles on the roads reduces the benefits of improved technologies. Innovation in manufacturing is effective; however it must be integrated with good driving habits, proper car maintenance and, ultimately, less reliance on the automobile for getting around.

A 16-kilometre trip in light traffic lasting 11 minutes would produce two grams of volatile organic compounds (VOC); the same trip in heavy traffic lasting 30 minutes would generate seven grams, a 250 percent increase in VOC emissions.

Understanding car exhaust: complete and incomplete fuel combustion

Automobile emissions result from the combustion of automotive fuels. The products of incomplete combustion are unburned hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide and water. Under ideal burning conditions, the products of combustion are carbon dioxide, water and nitrogen. Although carbon dioxide is a naturally occurring gas, elevated levels due to human activity contribute to climate change. Nitrogen oxides, hydrocarbons and carbon monoxide contribute to the formation of smog and acid rain.



Complete combustion

Fuel (hydrocarbons) + air (oxygen and nitrogen) = carbon dioxide + water + nitrogen

Typical fuel combustion

Fuel + air = unburned hydrocarbons + nitrogen oxides + carbon monoxide + carbon dioxide + water

On average, each car emits over five tonnes of air pollutants annually, comprising carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (including volatile organic compounds or VOC) and carbon dioxide (CO_2). Fifty-seven million tonnes of CO_2 were emitted from cars during 1994, accounting for 10 percent of total CO_2 emissions in Canada. Although CO_2 itself is not harmful to human health, and is considered a product of complete fuel combustion, it is the dominant greenhouse gas contributing to climate change.

The automobile, together with all other modes of transportation, is responsible for about 60 percent of total Canadian emissions of CO_2, CO, and hydrocarbons (including VOC), while two-thirds of all NO_x emissions (from human sources) come from transportation. These emissions can be harmful to the environment.

People today are driving more often and farther distances than ever before, and improvements in automobile technology are unable to offset the related damage. In order to balance society's need for mobility with environmental sustainability and human health, changes need to be made by policy makers, community planners and individuals.

For every 2,000 litres of gasoline consumed the average car produces:

- 4,720 kg of CO_2
- 186.8 kg of CO
- 28 kg of VOC
- 25.6 kg of NO_x

Air Quality in Canada

Issue:

The link between automobiles and pollution is most evident in urban areas when air quality exceeds acceptable concentration of pollutants (National Ambient Air Quality Objectives). A majority of Canadians believe that cars and trucks are the largest source of air pollution.

Air quality has been monitored in Canada since the early 1970s. Under the *Clean Air Act*, which has been largely incorporated into the *Canadian Environmental Protection Act*, National Ambient Air Quality Objectives for common air pollutants were established. Each year that measurements have been taken, the maximum acceptable levels have been exceeded for sulphur dioxide (SO_2) and ozone (O_3). Maximum levels were also exceeded for nitrogen dioxide (NO_2) and carbon monoxide (CO) except for the later years (1991-1995).

National Ambient Air Quality Objectives

Maximum Acceptable Concentration	Maximum Desirable Concentration
O_3* 82 ppb in 1 hour	50 ppb in 1 hour
NO_2 53 ppb annual	32 ppb annual
CO 31 ppm in 1 hour	13 ppm in 1 hour
SO_2 344 ppb in 1 hour	172 ppb in 1 hour
TSP* 70 micrograms/m^3 annual	60 micrograms/m^3 annual

O_3: ozone; TSP: total suspended particulate matter; SO_2: sulphur dioxide; NO_2: nitrogen dioxide; CO: carbon monoxide; ppb: parts per billion; ppm: parts per million

*The objectives for ozone and TSP are currently under review by the Federal-Provincial Advisory Committee to CEPA. Revised objectives are expected during 1998.

Air quality is monitored at stations throughout Canada by the National Air Pollution Surveillance (NAPS) network, a joint federal provincial program. NAPS has 130 monitoring stations in over 50 urban centres in Canada. In general, monitoring results from the NAPS network show considerable improvements in air quality. Some examples of the trends in common air contaminants are:

Annual Average Concentrations of Common Pollutants

- CO annual average concentrations decreased 70 percent from 1974 to 1993;
- NO_2 annual average concentrations decreased 36 percent from 1978 to 1993;
- SO_2 annual average concentrations decreased 60 percent from 1974 to 1993; and
- TSP annual average decreased 54 percent from 1974 to 1993.

There has been about a 50% reduction in peak ground-level ozone events nationally since 1979, apart from the summer of 1988. As weather strongly influences ozone formation and movement, the hot summer of 1988 favoured ground-level ozone formation.

The phase-out of lead from gasoline began in 1974. Since then, lead concentrations in ambient air have declined by 97.5 percent (practically disappearing from TSP filters). However, TSP themselves still remain a dominant factor in determining local air quality.

Despite the reduction of national levels of common pollutants, poor air quality remains a problem in large urban areas where their concentration occasionally reaches unacceptable levels.

2 Section Two
Science: The Environmental Impact

Transportation and the Environment: An Overview

Transportation has a variety of different impacts on the environment, including land use change, urban smog, climate change, acid rain, and energy and resource consumption.

This section describes how transportation is related to each of these issues and how it affects human health and the environment.

Smog:
A Regional Air-Quality Problem

Issue:

Automobiles produce approximately half the pollutants that combine to form ground-level ozone, the main ingredient in smog. In summer, smog can damage vegetation and have adverse effects on human health.

What is smog?

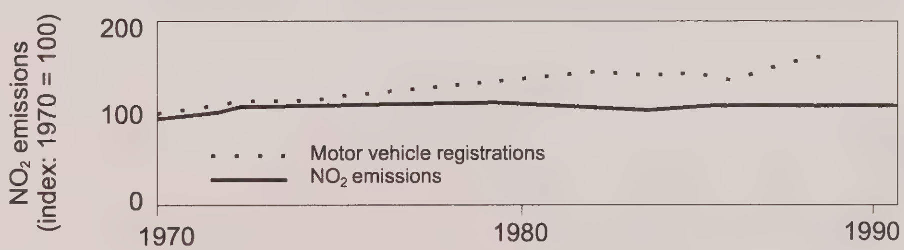
Smog is a mixture of many pollutants, including ozone and fine respirable particulate matter. Health Canada studies have found that there is an increase in emergency-room visits and hospital admissions for respiratory problems when smog levels are elevated. Ozone has also been shown to damage vegetation such as trees and crops.

Ozone is a highly reactive form of oxygen which is best known as the Earth's protective cover (the ozone layer) high in the stratosphere. However, at ground level, in the air we breathe, ozone is a powerful, irritating pollutant. It is formed when emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOC) combine in hot, stagnant air masses, in the presence of sunlight. This phenomenon generally occurs in the summer months.

NO_x emissions also come from the burning of fossil fuels to produce energy. VOC result when fuel is not completely burned, and from evaporation of volatile fuels such as gasoline. VOC also result from the evaporation of solvents used in paints and consumer products, and from industrial processes.

Personal vehicles (automobiles and light-duty trucks) alone produce 19 percent of NO_x and 22 percent of VOC emissions from all human sources. They also release fine particulate matter which can be inhaled deep into the lungs.

Emissions of NO_2 relative to motor vehicle registrations



Note: 1990 NO_2 emissions are projections.
Source: Statistics Canada; Environment Canada, Inventory Management Division

Reducing smog levels

Canada's environment ministers, through the Canadian Council of Ministers of the Environment (CCME), have developed a management plan for the reduction of nitrogen oxides and volatile organic compounds. The plan's overall goal is to meet Canada's ambient air objective for ozone in all areas of the country by the year 2005. Phase I of the plan contains a national prevention program (federally-led initiatives and codes of practice), regional remedial programs (federal-provincial agreements which set specific emission targets and reduction schedules for the three regions where ozone is most severe) and a study and investigation series (studies to determine final emission caps for Phase II).

On August 20, 1997, Transport Canada published comprehensive new motor vehicle emission regulations in the *Canada Gazette Part II*, pursuant to a recommendation of the CCME's Task Force on Cleaner Vehicles and Fuels. The new regulations establish stringent standards for 1998 and later model year vehicles and include requirements for the more effective control of pollutants which are contributors to smog.

The CCME's Task Force on Cleaner Vehicles and Fuels also recommended that Canada adopt low-emission vehicle standards for the 2001 model year. On December 21, 1996, Transport Canada initiated a public process to develop low-emission vehicle standards by means of a notice published in the *Canada Gazette Part I*. In related work, Environment Canada is leading a process to determine an appropriate level of sulphur for future Canadian gasoline which, as a minimum, will provide compatibility with low-emission vehicle technologies.

Climate Change:
Carbon Dioxide and the Greenhouse Effect

Issue:

Human activity is having a dramatic impact on the environment. One key concern is global climate change – the result of increasing levels of greenhouse gases which trap heat in the Earth's atmosphere. Canadian automobiles emitted 56.9 million tonnes of carbon dioxide in 1995.

Climate change refers to natural and human-induced changes in climate which occur over a period of decades to centuries. It is a change in the trends of interconnected weather elements such as temperature, wind patterns and precipitation. Widely accepted estimates predict that the Earth's average temperature might increase by about 0.3 degrees Celsius per decade during the next 100 years.

The greenhouse effect and global warming

The greenhouse effect is a heat-trapping process that keeps the Earth warm enough to sustain life. The Earth's atmosphere acts like the glass of a greenhouse – after sunlight passes through the atmosphere and warms the Earth, the heat is then radiated back towards space, but becomes trapped against the Earth by gases in the atmosphere. These heat-trapping gases are known as greenhouse gases.

An enhancement of the greenhouse effect has occurred as a result of increasing levels of these gases forcing more heat to become trapped against the Earth, causing an overall warming trend. The warming trend could significantly alter many important climatic features, such as rainfall patterns and regional drought. Tropical storms of greater severity and coastal flooding are also implications of global warming.

While global warming is a natural part of the Earth's climate cycle, recent human activities are having a detrimental influence on the delicate balance of greenhouse gases in our atmosphere. The burning of fossil fuels and resulting air pollution, deforestation, and some agricultural practices are upsetting this balance to the point that scientists are predicting major changes in world climate: rising temperatures, unusual shifts in rainfall patterns and changes in the world's food-growing areas. There is no doubt the effects on the ecosystems which produce and sustain life, including human life, could be dramatic.

Carbon dioxide - a potentially damaging greenhouse gas

Although water vapour, methane, nitrous oxide (N_2O), ozone and chlorofluorocarbons are all greenhouse gases, carbon dioxide (CO_2) is one of the most significant. In fact, CO_2 accounts for over half of the entire climate change trend. Canada produces about 2.5 percent of the world's total energy-related CO_2 emissions. Individual Canadians in their daily living contribute about 25 percent of the national total, on average about 5,500 kilograms of CO_2 per person, per year. This makes Canadians the second highest per capita CO_2 emitters in the world, second only to the United States.

Carbon dioxide, the automobile and global warming

Global carbon dioxide emissions are increasing at a rate of about 0.5 percent annually, mainly due to increased burning of coal, oil and gas that releases CO_2 into the atmosphere. Emissions from motor vehicles account for 14 percent of global CO_2 production from the burning of fossil fuels.

Canadian emissions of CO_2 have decreased on a per-vehicle basis in recent years as average fuel efficiencies have improved. However, total CO_2 emissions from automobiles still amounted to 57 million tonnes, in 1995, as a result of the increase in vehicle numbers and use. In Canada, automobiles account for 11 percent of total CO_2 emissions.

Global commitments

Canada and other industrialised nations are taking steps to improve the energy efficiency of business and industry in order to decrease the need for fossil fuel burning and reduce CO_2 emissions.

There are active efforts in Canada and on the international scene to meet the climate change challenge. Canada had pledged to stabilise greenhouse gases at 1990 levels by the year 2000. Although Canada, along with most other signatories, was not on track to meet this objective, endeavours to reduce greenhouse gas emissions continued.

Internationally, parties to the Framework Convention on Climate Change had set a goal of 1997 to negotiate policies and greenhouse gas reduction objectives for the post-2000 era. A new Protocol was signed in Kyoto, Japan, in December 1997. Canada has committed to reducing its greenhouse gas emissions by 6 percent below 1990 levels for the period between 2008 and 2012. This is similar to the commitments of our major trading partners, including the United States.

Canada's largest cities are taking a lead in responding to the challenge of climate change. As of September 1997, 30 cities are now members of the 20% Club and have committed to reducing emissions of greenhouse gases by 20 percent by the year 2005. On May 12, 1997, the City of Toronto announced that they had reduced their levels of greenhouse gas emissions to 1990 levels within their municipal operation - the first city in North America to do so.

Acid Rain

Issue:

Acid rain is a serious environmental hazard that endangers vegetation, wildlife and human health. Transportation based NO_x emissions are among the targets of Canadian and US acid rain reduction plans.

What is acid rain and how is it formed?

Acid rain is formed when sulphur dioxide (SO_2), and nitrogen oxides (NO_x) released into the atmosphere, combine with water in the air and form sulphuric and nitric acids. These acids can be carried in the air over long distances and are eventually returned to the Earth in the form of rain, snow, fog or dust. SO_2 emissions are the primary contributor but the relative importance of NO_x is increasing.

Nitrogen oxide emissions are formed during combustion of fossil fuels. The human activities that are responsible for these emissions are transportation (35%), industrial processes and fuel combustion (23%), power generation (12%), and other industries (30%).

Acid rain is more of a problem in eastern Canada, as the majority of SO_2 emissions originate from eastern Canadian industry as well as American sources. It is estimated that 50 percent of the acid rain that falls in eastern Canada originates from US sources.

Sulphur dioxide also forms tiny sulphate particles that travel deep into the lungs, harming human health and resulting in increased hospital admissions. These particles also form haze and impair visibility. Sulphur dioxide emissions are primarily caused by smelting, refining and the burning of fossil fuels for energy.

Reducing acid rain in the environment

The Canada-United States Air Quality Agreement addresses the issue of NO_x and SO_2 reduction. Measures include new federal guidelines for stationary combustion engines, and new NO_x emission standards for motor vehicles and appliances. However, NO_x emissions have remained fairly constant, and Canada and the United States have embarked on long-term reduction programs.

The Canadian Acid Rain Control Program began in 1985. A 56 percent reduction in emissions of SO_2 from 1980 levels has been achieved in eastern Canada. Canada has also met its national SO_2 cap of 3.2 million tonnes per year. Although national SO_2 emissions are down by nearly 50 percent from 1980 levels, scientists are predicting that large areas of the country will still remain acidified in the year 2010. Accordingly, Canada is developing a National Strategy on Acid Rain to manage these acid-sensitive areas after the year 2000.

SO_2 Emission Reduction Goals

Canada

- Emissions reduction in 7 eastern-most provinces to 2.3 million tonnes* by 1994
- Maintenance of 2.3 million tonnes annual cap for eastern Canada through December 1999
- Permanent national cap on emissions of 3.2 million tonnes by the year 2000

United States

- Emissions reduction of 10 million tons* from 1980 levels by the year 2000
- Permanent national cap of 8.95 million tons for electric utilities by the year 2010
- National cap of 5.6 million tons for industrial source emissions beginning in 1995

** One ton is equal to 0.9 tonnes. One tonne is equal to 1.1 tons.*

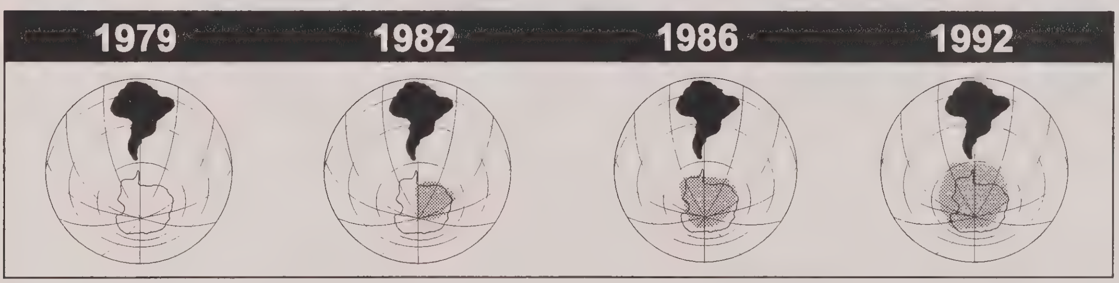
Stratospheric Ozone Depletion

Issue:

The Earth's fragile sun-screen is thinning due to the release of ozone-depleting substances such as CFCs that come from automobile air conditioners and other sources.

What is the ozone layer?

The stratospheric ozone layer is a thin layer of gas located in the upper atmosphere containing 90 percent of the atmospheric ozone. Unlike ground-level ozone (or smog) which is a powerful and irritating pollutant, this layer protects life on Earth from the sun's harmful ultraviolet rays. During the 1970s, scientists discovered a link between the weakening of the ozone layer and the release of ozone depleting substances into the atmosphere, such as chlorofluorocarbons (CFCs). Later, a "hole" (area of dramatic thinning) in the ozone layer was found over the South Pole, and world attention became focussed on the problem of ozone depletion.



Why is the ozone layer thinning?

Scientists have linked certain industrial chemicals with the gradual erosion of the Earth's fragile ozone layer. The primary offenders are CFCs, the chemicals traditionally used in air conditioners, refrigerators, freezers, solvents, foam manufacturing and aerosol products.

Other ozone depleting substances include methyl bromide, hydrochlorofluorocarbons (HCFCs), halons and carbon tetrachloride. All of these chemicals are part of a large class of industrial halocarbons which are compounds containing chlorine or bromine. These chemicals fuel the natural reactions that destroy ozone and can be found in almost every home or office in Canada – from refrigerators to fire extinguishers.

Transportation and the ozone layer

Air-conditioning systems in motor vehicles are the third most important source of CFCs in the atmosphere. There are roughly 14 million automobiles in Canada and approximately 60 percent of these vehicles are equipped with air conditioners. At an average of 1 kilogram per vehicle, there are 8.4 million kg of CFCs on the road today. Most vehicles leak CFCs and must be recharged an average of three times during their lifetime. Also, vehicles that are in accidents can release CFCs.

What is being done to protect the ozone layer?

At the end of the 1980s, some manufacturers had begun research into the use of less ozone damaging hydrofluorocarbons (HFCs) as a replacement for CFCs. In 1991, Mercedes Benz became the first company to sell cars in the United States using HFCs. In 1993, General Motors also began using HFCs in its vehicles, despite the fact that the change-over required a complete redesign of the air-conditioning systems. In 1995, all Canadian automobile manufacturers eliminated ozone depleting substances from air conditioners in new vehicles.

Recognising the potential severity of the ozone depletion problem, governments, policy makers, scientists, environmentalists and citizens from around the world have responded to the ozone crisis with an unprecedented pact for global co-operation.

Probably the most famous environmental agreement – in fact the world's first global environmental agreement – is the Montreal Protocol. The Protocol is an international agreement to halt the production and consumption of chemicals known to damage the ozone layer. As of January 1996, the production and consumption of CFCs is prohibited in industrialised countries, which means no more CFCs will be manufactured or imported for car air conditioners. Provincial regulations require that CFCs be recovered if they must be withdrawn from air conditioners. As well, in most provinces it is also illegal to recharge an air conditioner before repairing the leaks.

Hazardous Air Pollutants

Issue:

Combustion of gasoline can produce air pollutants which may be hazardous to human health. These must either be reduced by introducing less polluting alternatives or captured before they contaminate the atmosphere.

Hazardous air pollutants and the automobile

In addition to air pollutants such as NO_x, CO_2 and CO, which generally are emitted in large quantities, smaller amounts of potentially toxic substances are present in our atmosphere that can have harmful effects on our environment and our health. These substances are known collectively as hazardous air pollutants.

Automobiles are significant sources of several hazardous air pollutants, including particulate matter, benzene, polycyclic aromatic hydrocarbons and aldehydes.

Particulate matter are tiny airborne particles that can carry toxic substances, including heavy metals and chemicals, and cause irritation to the lungs. In cities, exhaust from diesel trucks and buses is a significant source of particulate. Other effects of suspended particulate matter include reduced visibility, soiling through deposition, and the formation of acid aerosols.

Polycyclic Aromatic Hydrocarbons (PAHs) are found in exhaust emissions from internal combustion engines, particularly diesel engines. Some PAHs adhere to particulate matter. PAHs are highly toxic to aquatic organisms and are thought to be human carcinogens.

Benzene is naturally present in crude oil and, like lead, acts as an octane enhancer. Octane enhancers prevent the fuel from igniting prematurely and causing engine damage. In an automobile, benzene is present in gasoline exhaust, and to a lesser extent evaporates into the air during refuelling or operation of the vehicle. Benzene may be released during storage and distribution of gasoline. Benzene is carcinogenic, posing a threat to human health.

Aldehydes are a group of chemicals emitted from car exhaust as a result of incomplete combustion. Although all aldehydes are suspected carcinogens, formaldehyde is the most significant.

What is being done?

In June 1988, the *Canadian Environmental Protection Act* (CEPA) was passed, establishing a Priority Substances List (PSL) of 44 substances including benzene and PAHs. Further renewal of CEPA is now underway.

Benzene has been found to be toxic under CEPA and has been added to the List of Toxic Substances. New regulations have been adopted under CEPA to limit the amount of benzene in gasoline, beginning on July 1, 1999. The *Benzene in Gasoline Regulations* were published in the *Canada Gazette Part II* on November 26, 1997.

Environment Canada is currently developing an inhalable particulate matter management strategy. In addition, Air Quality Objectives and Guidelines for inhalable particulate matter are now being updated by Environment Canada and Health Canada. On August 20, 1997, Transport Canada published comprehensive new motor vehicle emission regulations in the *Canada Gazette Part II*. As part of these new regulations, 1998 and later model year light-duty vehicles, light-duty trucks and heavy-duty vehicles are required to comply with more stringent emission standards for particulate matter. Notwithstanding the above, manufacturers of heavy-duty engines and vehicles had already been meeting the more stringent particulate standards on a voluntary basis since the 1995 model year under a Memorandum of Understanding signed with Transport Canada.

Lowering the sulphur content of diesel fuel results in reductions in vehicle emissions of primary air pollutants, including those of particulate matter. On February 19, 1997, Environment Canada published new regulations in the *Canada Gazette Part II* to limit the sulphur content of on-road diesel fuel to a maximum of 0.05% of the fuel by weight. The *Diesel Fuel Regulations* came into force on January 1, 1998. Low-sulphur diesel fuel had already been available in approximately 50% of the on-road market since October 1994, under a Memorandum of Understanding between Environment Canada and oil refiners.

Automobile Emissions, Individual Health and the Environment

Pollutants From Automobiles	What It is	Health Impacts	Environmental Impacts
Nitrogen Oxides (NO_x)	Nitric Oxide (NO) is the major NO_x component and oxidizes into nitrogen dioxide (NO_2) in the presence of hydrocarbons and sunlight. NO_2 reacts with hydrocarbons to form ozone or with water to form nitrate (NO_3), a significant source of acid rain.	• odour • increased sensitivity of asthmatics and those suffering from bronchitis • NO_2 is a lung irritant which can produce pulmonary edema at high concentrations • increased susceptibility to respitory infections in young children and the elderly	• NO_2 reacts with water to form nitrate (NO_3), a source of acid rain • Acid rain accounts for an annual loss of $197 billion in commercial forest wood products and a further $1.3 billion due to recreation and wildlife habitat destruction • NO_2 contributes to the corrosion of metals and degradation of textiles, rubber and polyurethane • NO_2 is associated with suppressed vegetation growth • NO_2 contributes to ground-level ozone formation • NO_2 contributes to stratospheric ozone depletion
Carbon Monoxide (CO)	CO is a colourless, odourless and tasteless gas produced through the incomplete combustion of organic materials. Personal vehicles are one of the main sources of CO, accounting for 54% of total CO emissions. Cars operating at colder temperatures (during winter or engine warm-up) produce significant quantities of this poisionous gas.	• CO reduces the ability of the blood to carry oxygen, and smokers, persons with heart disease, and those with anemia are especially sensitive • greater susceptability to respiratory infections in children and elderly	• CO released into the atmosphere depletes the atmosphere's supply of OH (hydroxyl radical) which is the main natural cleansing agent of the atmosphere. As a result, CO emissions contribute to increases in methane, partially halogenated CFCs and the formation of ozone under certain NO_x conditions.

Pollutants From Automobiles	What It is	Health Impacts	Environmental Impacts
Carbon Dioxide (CO_2)	CO_2 is a gas that comes from the decay of materials, respiration of plants and animal life and the natural and human-induced combustion of materials and fuels. Since the industrial revolution, the natural cycle of release and absorption of CO_2 in the atmosphere has become unbalanced due to an increase in human-produced CO_2 which contributes to global warming.	Indirect impact includes: increased deaths related to heat waves, dramatic weather events, increased transmission of vector-borne and infectious diseases.	• CO_2 is the most significant greenhouse gas contributing to global warming
Hydrocarbons (including VOC)	A numerous and chemically diverse group of compounds, non-methane hydrocarbons and volatile organic compounds (VOC) are important in the formation of ozone. VOC have at least one carbon atom and evaporate easily.	• many individual VOC (e.g., benzene) are known to have or are suspected of having human health effects ranging from carcinogenicity to neurotoxicity • some hydrocarbons from diesel emissions are carcinogenic	• VOC contribute to the formation of ground-level ozone
Ozone (O_3)	Ozone is formed when NO_x and VOC combine in the presence of sunlight.	• decrease in lung function • eye irritation • decreased immune function • possible long term role in the development of chronic lung disease	• reduced agricultural productivity in crops including soybeans, tomatoes, potatoes and corn • reduced growth rate in trees including red spruce, yellow pine and sugar maple • ground-level ozone is a global warming agent
Suspended Particulates	Suspended particulates are small particles of solid and liquid matter found in most fuel emissions but are found in significantly higher quantities in diesel emissions.	• small particles can penetrate lungs and cause respiratory infections • toxic particles can be taken into the blood stream • effects vary with the type of particulates	• decreased visibility • aesthetic damage to buildings

3 Section Three
Facts on Fuels

Modifications and Improvements to Diesel Fuels

Issue:

Improvements to diesel fuels will result in lower emissions of particulate matter and nitrogen dioxide from trucks and other diesel engines. Nitrogen dioxide is an important component of smog and particulate matter may contribute to respiratory problems in people.

Low-sulphur diesel and diesel exhaust emissions

The two main pollutants emitted by heavy-duty diesel vehicles are nitrogen oxides and particulate matter. Nitrogen oxide emissions contribute to environmental problems such as acid rain and ground-level ozone. Particulate emissions from diesel engines can be harmful to human health.

Particulate matter can be divided into two categories: primary and secondary particulate. Primary particulate is formed during the fuel combustion process in the engine, and is released as exhaust from the tailpipe. Primary particulate includes soot, the soluble organic fraction which contains polycyclic aromatic hydrocarbons (PAHs), and sulphate. Secondary particulate is formed when sulphur dioxide (SO_2) emissions from diesel exhaust are converted to sulphate particulate in the atmosphere.

Health and environmental effects

Since diesel particulate is released at levels that result in direct exposure, it can be especially harmful to human health. Particulate matter can be inhaled deep into the lungs and may build up over time, leading to increased susceptibility to lung infections, aggravated respiratory conditions such as asthma, and chronic lung disease. In addition, preliminary data suggests some PAHs in diesel particulate are potentially carcinogenic to humans.

As well as these health effects, particulate matter from diesel engine exhaust absorbs and scatters light, reducing visibility. Its black colour and oily nature result in the formation of a soil sediment when exhaust fumes are deposited on a surface. Diesel exhaust also has an unpleasant odour.

Heavy-duty diesel engine emissions standards and low-sulphur diesel fuel

Particulate emissions were first regulated in 1988, when Canada adopted a set of strict heavy-duty diesel emissions standards. Subsequently, the US Environmental Protection Agency (EPA) required 1994 model year heavy-duty vehicles to meet the most stringent emissions standards that technology would allow. The technology suggested by vehicle manufacturers and the petroleum industry to meet these new standards included catalytic converters and low-sulphur diesel (LSD) fuel. Catalytic converters reduce the soluble organic fraction (containing polynuclear aromatic hydrocarbons), which accounts for 25 percent of diesel exhaust particulate. However, the catalytic converter increases the conversion of sulphur to sulphate particulate, which may in turn plug the catalytic converter.

Sulphur in significant quantities can contaminate the metals used in the catalyst and render it ineffective. For these reasons, LSD must be used for the catalytic converter to work properly.

A Memorandum of Understanding (MOU) was signed by Environment Canada and Canadian fuel producers to ensure that the sulphur content of diesel fuel sold at retail outlets, about 50% of the on-road diesel fuel market, did not exceed 0.05% of the fuel by weight (i.e. LSD) beginning on October 1, 1994. Similarly, Transport Canada signed a MOU with heavy-duty vehicle and engine manufacturers to ensure Canadian 1995 - 1997 model year heavy-duty vehicles would meet the same stringent emission standards as applicable in the US.

On October 23, 1995, the CCME endorsed the report of its Task Force on Cleaner Vehicles and Fuels. The report recommended that Transport Canada harmonize its vehicle emission regulations with the US federal regulations and that Environment Canada adopt a national standard requiring the 100% provision of low-sulphur diesel fuel for on-road applications. On February 19, 1997, Environment Canada implemented the CCME recommendation concerning diesel fuel by publishing the *Diesel Fuel Regulations* in the *Canada Gazette Part II*. The *Diesel Fuel Regulations* ensure that the sulphur content of all-road diesel fuel does not exceed 0.05% of the fuel by weight beginning on January 1, 1998. In addition, on August 20, 1997, Transport Canada published new emission regulations for 1998 and later model year vehicles in the *Canada Gazette Part II* which include more stringent emission standards for heavy-duty diesel vehicles.

The cost and benefits of further reducing the sulphur content of diesel fuel, including diesel fuel used in off-road vehicles, is being examined by a federal-provincial government working group.

Reformulated Gasoline

Issue:

As air pollution and vehicle use increase, researchers are modifying conventional fuels to produce alternatives, such as reformulated gasoline, which reduce harmful emissions.

What does the term reformulated gasoline mean?

Conventional gasoline is a complex mixture of various chemical compounds known as hydrocarbons. Reformulated gasoline is simply gasoline that has undergone some change in its composition, while still maintaining acceptable performance. The reformulation process can range from mild changes in composition (such as removing some of the butane), to substantial alteration of the fuel's make-up. Currently, this kind of gasoline is only available to limited markets, because of the cost of refinery modifications needed to produce this specialised fuel.

How can reformulated gasoline help the environment?

Individual refineries can produce reformulated gasoline that meets specific performance requirements. This is accomplished by manipulating certain components of the gasoline to reduce carbon dioxide and other emissions.

In general, reformulated gasoline produces lower evaporative emissions and also reduces the emissions of ozone precursors and toxic pollutants compared to conventional fuels.

The following are specific examples of what various kinds of reformulated gasoline can do for the environment:

- By lowering volatility (rapid evaporation), evaporative emissions are reduced.
- By lowering sulphur content, catalytic converters will operate more efficiently and therefore exhaust hydrocarbons, nitrogen oxides and carbon monoxide emissions are reduced.
- By lowering levels of aromatics (organic compounds with an unsaturated ring, such as benzene), exhaust toxins are reduced.
- By adding oxygen containing compounds (known as oxygenates) such as alcohols or ethers, exhaust hydrocarbons and carbon monoxide emissions are reduced.

The Canadian Council of Ministers of the Environment (CCME) has identified the need for a regulation establishing a minimum national standard for gasoline. Environment Canada is currently formulating a draft gasoline standard that will set maximum limits for benzene, sulphur, aromatics and olefin.

Alternative Fuels

Issue:

Alternative fuels, such as liquefied petroleum gasoline (propane), natural gas, methanol and ethanol, have the potential to reduce emissions of hydrocarbons, hazardous pollutants and greenhouse gases.

Serious interest in alternative fuels began during the energy shortages of the mid-1970s. Scientists investigated other forms of fuels which could be used in spark ignition engines. More recently, interest in alternative fuels has been renewed because they may have environmental benefits.

The most common alternative fuels today are propane, natural gas, methanol and ethanol. In general, these fuels have the potential to reduce hydrocarbon emissions, air toxics such as benzene, and global warming effects. However, it is important to understand the complete life cycle of each fuel. The life cycle concept is a "cradle to grave" systems approach for thinking about products and services. This approach recognises that all life-cycle stages (raw material acquisition, manufacturing, transportation and distribution, use and disposal) have associated environmental and economic impacts. This means, for example, that the amount of energy used to make and store fuels, and the pollution generated in doing so, would have to be considered when evaluating the benefits of alternative fuels.

Although these fuels have the potential to offer environmental benefits over conventional gasoline and diesel, the benefits can only be realised if the technology of the vehicle has been properly adapted to the new fuel. At first, most natural gas and propane fuels were used in conventional vehicles that were adapted for the new fuel. While the vehicle might perform satisfactorily, fuel efficiency and emissions were not optimal. In many cases these conversions produced more pollution than the original gasoline engine. In the last few years, a limited selection of vehicles powered by propane and natural gas have been available directly from major manufacturers. Known as Original Equipment Manufacturer (OEM) vehicles, they are researched, engineered and certified to meet all emissions and safety regulations that apply to the equivalent gasoline vehicle.

On August 20, 1997, Transport Canada published comprehensive new motor vehicle emission regulations in the *Canada Gazette Part II* for 1998 and later model year vehicles. In addition to prescribing more stringent emission standards for gasoline and diesel-fuelled vehicles, for the first time the new regulations include emission requirements for vehicles operated on methanol, natural gas and liquefied petroleum gas.

Natural Resources Canada is a good source of additional information on alternative fuels.

Propane

Issue:

Propane fuel has the potential to burn more cleanly than gasoline and could therefore be less damaging to the environment. In addition to improving engine efficiency, propane is a practical and low-priced alternative to conventional fuels because the infrastructure for its use already exists.

Chemically speaking, propane is a gaseous hydrocarbon of the alkane series. As a fuel, propane – or, more accurately, liquefied petroleum gas (LPG) – is composed mainly of propane with small amounts of ethane, propylene and butane. Propane has been used for decades as a heating and cooking fuel supplied in the familiar pressurised steel bottles. It has also been used as an internal combustion engine fuel in fork lifts and other machinery, but has only been seriously considered as a transportation fuel since the early 1980s.

Where does propane come from?

Approximately 85 percent of Canada's propane, about 20.6 million litres per day, is extracted from natural-gas wells at gas plants in Western Canada. The remaining 15 percent is produced during the processing of petroleum at oil refineries.

Propane and the environment

When used in a properly prepared engine, propane could combust more completely than gasoline. This would result in lower levels of exhaust and evaporative emissions that contribute to urban pollution and climate change. Propane contains no aromatic compounds, and produces no benzene and particulate emissions.

Propane has a higher octane rating than gasoline, which means engines optimised to use this alternative fuel could improve energy efficiency and reduce emissions of the main greenhouse gas, carbon dioxide.

Availability of auto propane

Propane is a popular alternative fuel choice because an infrastructure of pipelines, processing facilities and storage already exists for its efficient distribution – propane is currently available at over 5,000 service stations in Canada. With an octane number of 100, propane can be used as a premium grade fuel.

Economics of propane

In certain locations, propane can offer a price advantage over gasoline. Many organisations have already recognised the cost advantages of switching to an alternative fuel like propane. For example, United Parcel Service (UPS) Canada is a courier company operating 1,300 delivery vehicles that consume over 12 million litres of fuel annually. After extensive research and planning, UPS decided that converting 70 percent of its Canadian fleet to an alternative fuel made environmental and economic sense. Pilot tests showed that the new fuels reduced the fleet's emissions while still maintaining acceptable vehicle performance.

The future of propane as an alternative fuel

Recent developments in "liquid fuel" injection for this alternative fuel will significantly improve the performance of propane vehicles, while reducing the cost and complexity of the fuel system. New self-serve propane refuelling should further increase the marketability of propane vehicles. Propane is, however, a less concentrated source of energy than gasoline, placing some limits on the range of the vehicles between refuelling.

Natural Gas

Issue:

Low-priced and abundant in supply, natural gas represents a growing export market for Canada. Natural gas is an inflammable gas (mainly methane) that is found in the Earth's crust. Natural gas reserves are found in western Canada and the United States in sandstone and carbonate reservoirs.

Natural gas and the environment

When used in a properly prepared engine, natural gas could combust more completely than gasoline. This would result in lower levels of the exhaust emissions that contribute to urban pollution and global warming. Natural gas contains no aromatic compounds and produces no benzene emissions. Also, when used to replace diesel fuel in a compression ignition engine, natural gas does not produce any particulate matter.

Natural gas has a higher octane rating than gasoline, which means engines optimised to use this alternative fuel could improve energy efficiency and reduce carbon dioxide, the main greenhouse gas.

Conversion to natural gas for vehicles

Many commercial vehicle operators see natural gas as a plausible alternative because it is virtually half the price of petroleum-based fuels. In fact, natural gas is a proven technology – vehicles have been running on it for the last 20 to 30 years. As well, adapting traditionally fuelled vehicles to natural gas is straightforward, although expensive. Conversion costs can range upwards of $2,600, depending on the vehicle type, and the number and size of storage tanks for the natural gas itself. Conversions make the most economic sense for highly used vehicles such as taxis, delivery trucks and utility vehicles, which will recover the cost of conversion quickly. Today there are several options for conversion, including a system that can run both on gasoline and natural gas.

Economic considerations and the future of natural gas as an alternative fuel

Many organisations have already recognised the economic advantages of switching to alternative fuels such as natural gas. For example, after extensive research and planning, the American Division of the United Parcel Service (UPS) decided that converting its entire fleet to natural gas made economic sense. Pilot tests showed that the new fuel reduced the fleet's emissions while still maintaining acceptable vehicle performance.

While the price of natural gas at the pump is the lowest of the alternative fuels, it must be remembered that there is no federal excise applied to natural gas as a vehicle fuel. Some provinces (British Columbia, Ontario and Quebec) have reduced or have no provincial taxes on natural gas. The economic incentive for using natural gas could disappear if these taxes are applied to the pump price.

The future of natural gas for vehicles

Although it is a non-renewable natural resource, natural gas is in abundant supply in Canada and the export market is currently growing. Electronically controlled gaseous fuel injection systems for this alternative fuel were developed in 1992, which improved the performance and reduced the emissions of natural gas vehicles. Auto manufacturers are planning to produce a wider selection of dedicated natural-gas vehicles by the late 1990s.

Methanol

Issue:

When used in a specialized factory produced vehicle, methanol could combust more completely than gasoline.

What is methanol?

Methanol is a type of alcohol, currently made from natural gas but which can also be made using biomass (wood waste or garbage) or coal. Unlike petroleum based hydrocarbon fuels like gasoline, that are made up of only hydrogen and carbon, methanol is an oxygen-containing fuel. This bound oxygen results in methanol having significantly different physical and chemical properties from typical hydrocarbon fuels. Methanol has been used for decades in a wide variety of industrial and consumer applications, and has been used as a racing fuel in Indy cars, dragsters and other high power applications. Only recently has methanol been investigated for use in ordinary cars and light trucks, and as a replacement for diesel fuel in heavy-duty trucks and buses.

Methanol and the environment

When used in a properly prepared engine, methanol could combust more completely than gasoline. This would result in lower levels of the exhaust emissions that contribute to urban pollution and global warming. Methanol contains no aromatic compounds and therefore produces no benzene emissions. Full analysis of all of the energy and materials required to produce and distribute methanol must be done, however, before the true environmental impact of large scale methanol use can be determined.

Methanol and the transportation industry

Canada's current transportation system primarily uses fuels derived from oil. In the early 1980s, methanol was seen as one possible replacement for conventional gasoline and diesel fuel. Methanol is one of two currently available alcohol fuel alternatives to gasoline or diesel fuels: the other being ethanol. Methanol and ethanol have similar, but not identical, properties and both are different in many ways from conventional hydrocarbon fuels.

Alcohol fuels such as methanol can be used in two ways in transportation applications:

1) Neat Fuels - vehicle and engine systems can be altered to run exclusively on methanol as opposed to gasoline (the most advanced technology, known as flexi-fuel or variable fuel, allows an engine to operate on straight methanol or straight gasoline – or any mixture of the two – without re-tuning the engine). For safety

reasons, the content of methanol is limited to 85% maximum of methanol (referred to as M85). Methanol has a higher octane rating than gasoline, which means engines optimized to use this alternative fuel could improve energy efficiency and reduce emissions of the main greenhouse gas, carbon dioxide; or

2) Fuel Blends - methanol can be mixed in small amounts (up to 5%) with gasoline to extend or improve the performance of conventional fuels for use in vehicles that have not been modified in any way. Methanol is more corrosive than gasoline and requires additives to reduce this effect. Unfortunately, methanol also separates from gasoline in the presence of water and therefore requires a co-solvent such as ethanol, isopropanol, isobutanol or tertiary butyl alcohol, along with stringent handling procedures, to avoid water contamination.

The future of methanol

Canada has abundant raw materials for the production of alcohol fuels such as methanol. Tests of pure alcohol fuels have also proven successful even in severe cold winter and hot summer conditions. The greatest obstacle facing alcohol fuels, however, is availability. Methanol is currently distributed widely as a chemical commodity with very strict controls on quality. Wide distribution and availability of fuel methanol will be required before this alternative fuel can play a role in the transportation sector. Research is currently under way to reduce the cost of methanol production.

In the United States, methanol fuelling stations are available in California. The famous Indy 500 auto racing circuit continues to require methanol as the only fuel that can be used at Indy races.

Ethanol

Issue:

Ethanol blended with gasoline may be less damaging to the environment than conventional fuel.

What is ethanol?

Fuel ethanol is a high-octane, water-free alcohol produced from the fermentation of sugar or converted starch. In Canada, ethanol is made primarily from lower value grains, such as barley, feed wheat, and corn. Poor quality grains (weather-damaged or immature) and forestry wastes (sawdust, etc.) are also excellent feedstock for ethanol production.

Alcohol fuels, like ethanol, are a series of organic compounds that contain the hydroxyl group – an atom of oxygen bonded to an atom of hydrogen. Ethanol is different than conventional transportation fuels like gasoline and diesel because it contains oxygen as well as carbon and hydrogen (the conventional fuels lack the oxygen component), which permits the fuel to burn more completely than non-oxygenated fuels.

Ethanol and the transportation industry

Ethanol is one of two currently available alcohol-fuel alternatives to gasoline. Alcohol fuels such as ethanol can be used in two ways in the transportation industry:

1) Neat Fuel - vehicle engines can be altered to run exclusively on ethanol as opposed to gasoline. These vehicles are presently being demonstrated as a viable alternative to conventional vehicles and fuels; or

2) Fuel Blends - up to 10% ethanol can be mixed with gasoline to extend or improve the performance of conventional fuels, and since ethanol has a much higher octane number than gasoline, it is considered to be a viable octane enhancer.

Ethanol and the environment

Usually, ethanol is blended with gasoline to produce "gasohol", commonly called E5 (five percent ethanol) or E10 (ten percent ethanol). The Environmental Choice[M] Program (ECP), granted an EcoLogo[M] to these low-level blends.

Low-level ethanol blends can be considered an alternative to conventional transportation fuel because they may have a potentially less harmful impact on the environment. Ethanol, if it is blended properly, can reduce carbon monoxide and benzene emissions. However, the carbon monoxide benefit of ethanol over regular gasoline will diminish as the emission control technologies on cars become more sophisticated.

Carbon dioxide emissions can also be reduced when ethanol is derived from some biomass sources. While producing fuel ethanol by fermentation helps reduce greenhouse gas production, it has some disadvantages. Not only is the process to produce ethanol expensive, the energy required for distillation comes from burning natural gas or coal. These fuels produce greenhouse gas emissions and, therefore, decrease the net environmental advantage of using ethanol as a fuel. Furthermore, ethanol may increase aldehyde emissions.

The future of ethanol

Canada has abundant raw materials for the production of alcohol fuels such as ethanol. In fact, domestic automobile manufacturers have recently introduced "flexible-fuel" vehicles than can run on conventional fuel, ethanol or methanol blends. Tests of pure alcohol fuels have also proven successful even in severe cold winter and hot summer conditions.

Ethanol became popular in the American mid-west in the 1970s, and its popularity spread to Western Canada and continued eastward into Southwestern Ontario by 1991. The greatest obstacle facing alcohol fuels like ethanol, however, is one of economics. Ethanol is more expensive to produce than methanol, which in turn is more expensive to produce than gasoline. However, researchers are closer to finding cost-effective ways to convert plant cellulose to sugar, and there may even be ways to use the material left over after the ethanol has been removed.

Electricity and Hydrogen

Issue:

Zero emission vehicles powered by electricity or hydrogen may be a key to reducing consumption of non-renewable resources. However, several issues need to be resolved before these vehicles can be integrated on a large scale into the present transportation network.

Zero emissions vehicles and the environment

Hydrogen as a fuel holds great promise for the environment. It burns quickly and cleanly. Since hydrogen contains no carbon, it does not produce CO, CO_2 and VOC. However, because it does not exist in nature in pure form, hydrogen has to be extracted from other substances. The most energy-efficient source of hydrogen for transportation uses is water. Hydrogen can be extracted from water using electricity, a process known as electrolysis.

Electricity is derived from a number of sources such as coal, oil, gas, wood, nuclear power, water, wind and solar energy. Even though zero emission vehicles do not give off any harmful contaminants at source, if the electricity to power them results in environmental damage or releases harmful emissions, the environmental benefits may be negated. Electric- and hydrogen-powered vehicles are "cleanest" when renewable resources are used to generate the electricity.

With widespread electric vehicle use, other environmental repercussions such as battery production, transport, use and disposal will come under consideration.

As well as reducing greenhouse gases, urban smog and other air pollution problems aggravated by conventionally fuelled vehicles, zero emission vehicles are quieter and more energy efficient.

Zero emission vehicles and the transportation industry

Vehicles operated by electricity from a battery or a fuel cell using hydrogen are known as zero emission vehicles. The name comes from the fact that such vehicles do not directly emit any pollutants during their operation.

Electricity has been used for over a century to power public transit vehicles such as streetcars and subway trains. These vehicles run on a set track or cable that provides a constant source of electricity. Companies are developing self-contained, battery-powered light-duty vehicles which will be practical for urban, short-range commuting.

Another option for powering electric vehicles is the hydrogen fuel cell. Fuel cells generate electricity and water on board the vehicle by combining compressed hydrogen gas with oxygen from the air. This eliminates battery weight and recharging problems faced by other electrically powered vehicles. Recent technologies can also produce hydrogen on board the vehicle using fuels such as natural gas, propane, methanol and even gasoline.

Zero emission vehicle: market promise and manufacturing challenge

Manufacturers are investigating ways to expand the electric vehicle market to sustain the transportation industry. Conventional lead-acid battery technology must be improved to increase the vehicle driving range, lower the cost, and shorten the time needed for recharging. New battery types such as sodium-sulphur, lithium-aluminum and iron-sulphide batteries are also being developed. Hybrid vehicles that can run on electricity as well as other fuels such as gasoline, natural gas, propane, or methanol, are also being considered as an alternative to vehicles that run by battery only.

As electricity prices rise, manufacturers must find cost-effective methods to maintain and operate zero emission vehicles without increasing demand on the source of electric power. Presently, Canadian electricity supplies are sufficient to meet the demand if vehicles are recharged during offpeak periods.

The future of zero emission vehicles

Developments in the electric- and hydrogen-powered vehicle field are stimulated by increasingly stringent emissions regulations.

Electric vehicles, including hybrid electric vehicles, are already being produced in limited numbers. Hydrogen-powered buses, using technology developed in Canada, are being tested on the streets of Vancouver and Chicago. Mass use of hydrogen-powered vehicles, however, will require the development of a safe and economically viable way of producing, distributing and storing hydrogen.

MTBE/ETBE as Fuel Additives

Issue:

Oxygen-containing gasoline additives such as Methyl Tertiary Butyl Ether (MTBE) or Ethyl Tertiary Butyl Ether (ETBE) reduce certain emissions. They also function as octane enhancers.

What are fuel additives?

There are several different types of fuel additives, including alcohols, ethers and metals.

Oxygenates, which refers to oxygen-containing compounds such as alcohols or ethers, can be blended with gasoline in small amounts (usually 5 to 15 percent) to improve fuel quality. Some oxygenates can be used as fuel extenders, allowing other resources such as natural gas and biomass to replace part of the crude oil used to manufacture gasoline. This helps to conserve diminishing oil supplies. Fuel additives also act as octane enhancers, preventing the fuel from igniting prematurely and causing engine damage.

Lead was a fuel additive, used for over 60 years as an octane enhancer, before being banned in 1990 because of its adverse health effects. Since then, researchers have developed other, less-harmful alternatives that have the same fuel-improving qualities.

This fact sheet covers only two ethers, MTBE and ETBE, that are used as fuel additives.

Methyl Tertiary Butyl Ether

Methyl tertiary butyl ether (MTBE) is made from a mixture of methanol and isobutylene from oil refineries. It has a high octane value and a low volatility, and is thus an effective octane enhancer. It has an advantage over alcohol-blend fuels because it does not separate out in the presence of water.

A research program on fuels, underway in the United States, revealed that adding 15 percent MTBE to gasoline reduced hydrocarbons and carbon monoxide, but had no effect on nitrogen oxides or hazardous pollutants. Gasoline containing MTBE has been sold in the United States since 1979, and MTBE is currently the most popular oxygenate on the US market.

There has been concern in the United States over the contamination of surface and ground water with MTBE. MTBE is extremely persistent in water and may carry chemicals from gasoline along with it into drinking water supplies.

In Canada, MTBE is manufactured only in Edmonton. That means most MTBE must be imported from the United States at considerable cost.

Ethyl Tertiary Butyl Ether

Ethyl tertiary butyl ether (ETBE) is similar to methyl tertiary butyl ether except it is made from ethanol and isobutylene. ETBE also has a high octane value and offers a lower volatility than MTBE. Presently, ETBE is more expensive to produce than MTBE.

4 Section Four
Regulations, Controls and Standards

Emissions Standards
for Motor Vehicles

Issue:

Motor vehicle manufacturers are improving emission control and monitoring technologies to meet increasingly stringent vehicle emission requirements in Canada.

Motor vehicles are a major source of air pollution. Transport Canada promulgates standards under the *Motor Vehicle Safety Act* to limit the amount of specific pollutants that can be emitted by vehicles, and manufacturers must find ways of meeting these standards through the use of emission control and monitoring technologies.

For example, most cars today are equipped with catalytic converters. Catalytic converters are pollution control devices installed directly in the exhaust system of vehicles to reduce harmful emissions. First used in 1975, oxidation (or two-way) catalytic converters take hydrocarbons (HC) and carbon monoxide (CO) and convert them into carbon dioxide (CO_2) and water vapour, which are then released into the air. Three-way catalytic converters appeared in the mid-1980s, and convert carbon monoxide (CO) and hydrocarbon (HC) emissions as well as nitrogen oxide (NOx) into nitrogen, carbon dioxide and water vapour. Another milestone in vehicle emissions standards was the elimination of lead from gasoline in December 1990.

Since 1971, Canadian motor vehicle emission standards have been made progressively more stringent. The table on the following page provides an illustration of the evolution of Canadian exhaust emission standards for gasoline-fuelled vehicles. On August 20, 1997, Transport Canada published comprehensive new emission regulations in the *Canada Gazette Part II*. The new regulations require the more stringent control of exhaust emissions (HC, CO, NOx and PM), evaporative emissions (mostly HC) and refuelling emissions (mostly HC) from 1998 and later model year vehicles. The new regulations include tighter emission control requirements for light-duty vehicles, light-duty trucks, heavy-duty vehicles and motorcycles, operating on gasoline, diesel fuel, methanol, natural gas or liquefied petroleum gas. In addition, the new regulations require that new light-duty vehicles and light-duty trucks be equipped with on-board diagnostic systems to monitor vehicle emission control systems for proper functioning and to alert the driver of any malfunction by illuminating a dashboard light.

Canada's new vehicle emission standards are fully harmonized with those applicable in the United States under the Environmental Protection Agency's federal emission control program and are consistent with a recommendation of the CCME's Task Force on Cleaner Vehicles and Fuels.

Transport Canada has also initiated a public process to develop low-emission vehicle standards for the 2001 model year.

Light-duty Gasoline Vehicle Standards in Canada
Exhaust Emissions (g/km)

Effective Date	HC		CO	NO_x	PM
	THC	NMHC			
Prior to Standards (Estimates)	5.5	-	54	2.2	-
January 1971	1.4	-	14	-	-
July 1971	2.1	-	24	-	-
January 1973	2.1	-	24	1.86	-
January 1975	1.2	-	16	1.93	-
September 1987	0.25	-	2.1	0.62	-
September 1997	0.25	0.16	2.1	0.25	.050

HC: Hydrocarbons, THC: Total Hydrocarbons, NMHC: Non-Methane Hydrocarbons, CO: Carbon Monoxide, NO_x: Nitrogen Oxides, PM: Particulate Matter.

Note: Carbon dioxide (CO_2) emissions are essentially controlled by reducing fuel consumption rather than by pollution control devices.

In the case of the standards in place from 1971 through 1974, different test procedures were used to verify compliance. Therefore, their stringency cannot be directly compared with the other standards.

For the 1998 model year, similar standards exist for diesel, methanol, natural gas, and LPG vehicles.

For complete information about Canada's emission standards, please consult the applicable *Canada Gazette Part II*.

Evaporative
Emissions Controls

Issue:

Environment Canada and the Canadian Council of Ministers of the Environment (CCME) have developed new guidelines to reduce the evaporation of gasoline at service stations. Gasoline volatility is also regulated during the summer months in certain provinces to reduce evaporative emissions.

Transportation-related emissions result not only from fuel combustion when the automobile is in operation, but also from evaporation of the fuel itself before it is burned in the car engine. There are two methods to avoid evaporative emissions from gasoline fuel: vapour recovery and gasoline volatility limits.

Vapour Recovery Systems

Noxious vapours escape into the air every time gasoline is transferred from the terminal to the storage tank or from the gas pump to the vehicle gas tank. Approximately 110,000 tonnes of gasoline vapours are emitted each year by the Canadian gasoline distribution network. To remedy the problem, a task force made up of government, environment and industry groups developed vapour recovery system guidelines for gasoline storage, transfer and dispensing facilities. There are two stages to the vapour recovery process; Stage I and Stage II.

Stage I equipment ensures the recovery of vapours that escape during gasoline transfer from terminals and bulk plants to delivery at service station underground storage tanks. A code of practice for Stage I was published by the Canadian Council of Ministers of the Environment in March 1991. A code of practice gives guidance on the process of implementing Stage I, if required by provincial regulation. To date the Lower Fraser Valley of B.C. and southern Ontario have adopted Stage I regulation.

Stage II equipment prevents gasoline vapours from being lost when vehicles are refuelled at service stations. The vapours are captured at the vehicle fill pipe by a special nozzle and returned to the service station's storage tanks. One to two litres of gasoline are recovered per 1,000 litres dispensed.

An alternative to Stage II equipment is to prevent vehicle fuel tank vapours from escaping from the filler pipe during the refuelling process and routing the vapours to an on-board canister filled with activated carbon. The vapours are temporarily stored in the canister by being absorbed on the activated carbon and are subsequently purged from the canister and burned in the engine during vehicle operation. This type of system, known as **on-board refuelling vapour recovery** (ORVR), can reduce refuelling emissions by about 95%.

On August 20, 1997, Transport Canada published comprehensive new emission regulations in the *Canada Gazette Part II* which, in part, require that ORVR systems be phased-in on motor vehicles beginning with the 1998 model year.

A code of practice for Stage II was published by the CCME in April, 1995. Adoption of the code of practice is under provincial jurisdiction. Given that on-board vapour recovery systems will begin to be phased-in with the 1998 model year, provinces may choose not to adopt this code of practice.

Vapour recovery systems have been installed at terminals, bulk plants and service stations in the Greater Vancouver Regional District which required Stage I as of December 31, 1992. Within the Windsor-Quebec City Corridor, similar Stage I activity is also underway.

Gasoline volatility

Volatility is a measure of how susceptible a liquid is to evaporation. Low volatility gasoline has a lower rate of evaporation than regular gasoline. This means that fewer harmful vapours escape to pollute the air when low volatility gasoline is used.

Under the auspices of the Canadian Council of Ministers of the Environment Task Force on Cleaner Vehicles and Fuels, the CCME has agreed that lower Reid Vapour Pressure limits for the summer months for the Lower Fraser Valley and the Windsor-Quebec City Corridor will be adopted. The provinces will have to update their regulations in order to adopt these new proposed lower limits.

Inspection and Maintenance Programs

Issue:

A small percentage of the vehicle population produces most of the vehicle exhaust emissions in Canada. Poorly maintained or older vehicles are most often to blame and guidelines outlining programs to identify and repair these vehicles were published in 1994. Revised guidelines will be available in 1998.

All new motor vehicles sold in Canada must meet stringent pollution standards; however, if the vehicle is tampered with or the pollution control equipment is not properly maintained, the environmental benefits of improved technology are lost. Inspection and maintenance (I/M) programs are being set up in several areas across Canada in response to this problem.

What are I/M programs?

I/M programs involve the regular inspection of motor vehicles to verify the presence of pollution control equipment and to ensure compliance with provincial emissions limits. When a vehicle that exceeds pollution limits is detected, the vehicle must be repaired.

The requirement for a regular inspection will have two significant impacts. First, the inspection requirement will discourage tampering and will also act as a stimulus for the majority of motorists to improve or continue the proper maintenance of their vehicles. Second, those vehicles that fail the inspection will be required to undergo some level of repair. In general, these repairs must occur before the vehicle can be re-licensed for use.

To facilitate the development of a uniform and consistent approach to I/M programs across Canada, a task force made up of environmental groups, government, and industry stakeholders developed an *Environmental Code of Practice for Motor Vehicle Emission Inspection and Maintenance Programs*, published in fall 1994. The code is an initiative of the Canadian Council of Ministers of the Environment's *Management Plan for NO_x and VOC*, established in 1990 to resolve the smog problem in Canada by 2005.

I/M across Canada

I/M programs are recommended for areas where motor vehicles are a major source of harmful emissions, where air pollution is a problem, or as a pollution prevention measure.

British Columbia's AirCare program was the first I/M program to be made mandatory in Canada, and is expected to reduce levels of NO_x, VOC and CO from automobiles by 10 percent, 25 percent and 30 percent, respectively. Ontario recently completed a pilot I/M program, and is seriously studying the implementation of a mandatory I/M program. Smog Free, a voluntary program that ran in Calgary during the spring of 1993 and again in 1994, offered free vehicle emissions tests at participating service stations. Quebec has studied implementing I/M and announced a pilot program for the Montreal area. Several short-term voluntary emissions testing clinics have also run in Newfoundland, New Brunswick and Manitoba. Nova Scotia and Newfoundland perform tampering inspections on 1991 and newer vehicles when they undergo compulsory annual safety checks.

I/M programs are an effective way of ensuring Canada's vehicle fleet is as clean as possible, to preserve the quality of our air.

5 Section Five
Cross Cutting Issues

Transportation Demand Management

Moving away from the Single Occupant Vehicle

Issue:

Besieged by damaging air pollutants, the environment is suffering from society's automobile dependency. Faced with the dilemma of sacrificing convenience for air quality, individuals and organisations are working to change their transportation habits.

At the heart of current air pollution and traffic congestion problems is the single occupant vehicle (SOV). SOVs represent the most inefficient use of transportation energy. For example, in Vancouver, 98.4 percent of rush hour traffic consisted of passenger cars that carried only 62.6 percent of commuters.

Although there is no single mode of transportation that outdistances the automobile in popularity, several viable options do exist. Transportation demand management (TDM) refers to a series of strategies that can be taken to alter commuters' behaviour so they make better use of these alternatives, especially during peak rush hour periods.

Public transit

A full bus removes 40 vehicles from the road. This saves 70,000 litres of fuel and avoids nine tonnes of air pollutants a year. Public transit is most efficient during peak commuting periods, when buses are full.

Several transit companies are working on increasing ridership by promoting the environmental and economical benefits of mass transportation. The Toronto Transit Commission (TTC), for example, has 25 vehicles fuelled by natural gas. The TTC also encourages commuters to bike and ride by installing bicycle racks at all TTC stations.

In Vancouver, BC Transit relocated its main office directly on the Sky Train line, to encourage employee use of public transit and make commuting easier, faster and less polluting. Endeavouring to make its transit system as clean-running as possible, the majority of passengers travel on electrically powered vehicles.

The Hamilton Street Railway (HSR) is also at the forefront of environmentally oriented transit initiatives. HSR currently has 58 vehicles fuelled by natural gas.

Although effective for high density travel times, public transit vehicles can be inefficient energy users during off-peak hours.

Bicycles

Bicycles are a clean air alternative for those commuting over short distances. Recognising the environmental and health benefits of bicycle travel, several municipalities are investigating ways to make it more appealing to commuters. The Regional Municipality of Ottawa-Carleton has prepared a comprehensive cycling plan which fits in with the City of Ottawa's commitment to reduce CO_2 emissions, and aims to reduce the number of cars in the downtown core by increasing bicycle travel. In addition, the City purchased several bicycles to be used by employees for business purposes such as site inspection and meetings. As well, the use of bicycles by parking control officers has made the job faster and more efficient.

Bicycling is the only truly environmentally friendly mode of transportation and it is important that municipal regulations, zoning and road planning do not discourage it.

High occupancy vehicle lanes

Urban TDM strategies can also include high occupancy vehicle (HOV) lanes for carpools and buses. These lanes are restricted to vehicles carrying a certain number of people and allow the vehicles to travel under less crowded conditions, and arrive at destinations in less time. HOV lanes have indirect environmental benefits as they provide incentives to travel by carpool. In addition, they are generally less busy than regular lanes and therefore help keep traffic steady and improve fuel efficiency.

Carpools

Carpooling involves two or more people sharing a ride to a mutual, nearby or consecutive destination to save gasoline, driving and the environment. Carpooling is a practical and economical alternative to the SOV, and studies report high levels of satisfaction with carpools involving friends, families and co-workers. Incentives to promote carpooling involve priority parking privileges (costs and spaces), guarantee of emergency ride home, special lanes, flexible working hours, and help finding partners.

Many programs have been set up in the workplace and community to facilitate carpooling for employees and general commuters. In Ontario, the Share-a-Ride program has expanded from a government employeeonly program to a province-wide computer ride matching system for everyone using the 1-800-56-SHARE toll free line. BC's RideShare Toolkit provides all the information needed for organisations to set up and maintain a successful RideShare program.

The success of TDM measures depends on how well they meet the needs of commuters. Many employers are now helping make TDM measures possible by introducing flexible work schedules and telecommuting options. By switching to an alternative form of transportation, such as transit, cycling or carpool, there are less cars on the road, there is less need for roads and parking spaces and, ultimately, there is significantly less pollution.

Driving Behaviour and the Environment

Issue:

Which car you choose, when and how you drive it, and how you take care of it will determine how much your vehicle pollutes. There are significant measures that can be taken in all these areas to reduce the environmental impact of the individual automobile.

Despite better pollution control devices and more stringent emissions standards, ultimately, driving practices themselves will determine how much a vehicle pollutes. Fuel-efficient driving practices reduce harmful automobile emissions by consuming less gas. Several factors are involved in driving fuel efficiently, including vehicle selection, use, operation, maintenance, and type.

Vehicle selection

The type of vehicle selected determines the amount of fuel that will be consumed as well as its overall environmental impact. Vehicle weight, size, engine characteristics, accessories and fuel consumption rating are all factors to be considered when choosing a car.

Generally, lighter and smaller cars are more fuel-efficient. Through new technology, manufacturers are now able to produce cars of a lesser size and weight than older cars, which also saves materials and environmental resources.

Engine characteristics and transmission type also can affect fuel efficiency. The smaller the engine, the lower its fuel consumption will be. Vehicles with manual transmissions can be five percent more fuel-efficient than automatics, if driven properly.

Accessories such as power steering, four wheel drive, air conditioners and a sun roof add to a vehicle's fuel consumption. However, a number of options, such as diesel vehicles, fuel injection systems, shift indicator lights, block heaters and flow-through ventilation, can reduce the amount of fuel used and increase the environmental efficiency of the automobile.

To help choose the most fuel efficient vehicle, the Government of Canada publishes a *Fuel Consumption Guide* every autumn which can be picked up at participating new car dealers, most vehicle license offices, and most Credit Union and Caisse Populaire offices.

Vehicle use

Limiting the number of kilometres driven is by far the best way to reduce air pollution. Our dependence on automobiles has increased, but simple preventive measures like trip and route planning can dramatically reduce the amount we drive as well as the environmental impacts when we do decide to take our car.

Cars are least efficient when driven in stop-and-go traffic. A trip taken during typical rush hour congestion takes more time, uses more fuel and releases more emissions than driving at off-peak periods when traffic is lighter. Listening to the traffic report will help plan a route that avoids busy areas.

A catalytic converter is most efficient when it is warmed up. After 10 minutes of operation, the car pollutes less. Combining several errands into one single trip will lessen the total distance driven and keep the catalytic converter at peak efficiency.

Vehicle operation

A major factor determining the amount of fuel used and thus the amount of emissions released is the way the vehicle is operated. Speed, acceleration, breaking, idling, momentum and accessory use must all be considered to drive fuel efficiently.

As drivers increase car speed during highway driving, the engine works harder and therefore pollutes more. Above 100 km/hr, fuel loss is about one percent for each kilometre per hour increase in speed. Most automatic and standard transmission vehicles are equipped with an overdrive gear that reduces the fuel consumption and the wear on the engine while operating at highway speeds.

If an engine idles for longer than one minute, more pollution is created than if the car were to be turned off and re-started. In the winter, the car engine needs only to be warmed up for 30 seconds. Smooth stopping and slow acceleration also burns less gas.

Refuelling can cause spillage, releasing extra gasoline vapours into the air that contribute to ground-level ozone. So when the automatic nozzle shuts off, do not re-start the pump and add more fuel to the tank.

Accessories that reduce the fuel efficiency of the vehicle should be used sparingly. Air conditioners can increase fuel consumption by up to 12 percent in stop-and-go traffic, and roof racks can add to the amount of fuel used by as much as 25 percent when loaded and 1 percent when empty.

Vehicle maintenance

Although cars manufactured today are equipped with sophisticated pollution control devices, this equipment must be properly maintained in order to minimise vehicle pollution. Improper maintenance can increase emissions as much as 10 times the expected amount. A regular tune-up ensures all the vehicle components are working properly, and prevents unnecessary pollution.

Manufacturers recommend following the maintenance steps and schedules in the owner's manual to ensure the vehicle is in top condition. The oil must be changed regularly, the filters and spark plugs replaced, the fuel injectors cleaned and the drive belts and battery checked. Tires also must be kept at the right pressure and rotated regularly. If tires are under-inflated, fuel consumption can increase by as much as eight percent.

Vehicle type

Older vehicles, although representing a smaller percentage of total cars on the road, and driven fewer kilometres, still contribute more to air pollution than newer, more fuel-efficient vehicles. In 1991, 50 percent of air pollution was generated by only 10 percent of the total vehicle population, the majority of which were older or improperly maintained.

Since new cars are responsible for only a small percentage of air pollution that exists today, to reduce vehicle emissions, it may make sense to remove older, fuel-inefficient vehicles from the road and ensure new, fuel-efficient vehicles are operated and maintained properly. Mandatory periodical vehicle inspection programs would identify cars that don't comply with emissions standards and ensure that they are repaired or replaced.

There are many benefits to driving fuel-efficiently. Not only does it help protect the environment, it also conserves energy, improves safety and results in substantial financial savings.

Automobile Infrastructure

Issue:

Cars are costly. On average, people spend 4 of their 16 waking hours driving a car or generating the resources to pay for it. Most car owners consider only the cost of purchasing a car, and pay little attention to the indirect costs.

Usually our immediate concern about the cost of cars is the purchase price. However, the Canadian Automobile Association estimates the average annual operating cost of a car to be at least $7,000 a year. Parking downtown adds between $60 and $200 per month.

While we enjoy the convenience of the automobile, it is the least energy efficient form of transportation. In addition, there are numerous costs associated with motor vehicle travel that we do not consider, including the costs of road construction and maintenance, time costs for rush-hour congestion, accidents and fatalities, traffic law enforcement, environmental impacts and the cost of lost land opportunities.

Measuring the full costs of the automobile, whether they be environmental, economic (both public and private) or health costs, is a complex task. Given that there is no single best approach to assess these costs, this fact sheet examines some of the infrastructure costs of cars in our society.

Infrastructure

Canadian cities are characterised by segregated land-use patterns that separate home, work, shopping and recreational facilities. This development pattern makes it difficult to build cost-effective public transit systems. As a result, car rides account for 85 percent of all personal trips made in a city.

Who Pays?

Ultimately we all pay for poor land-use patterns and increased traffic. Specifically, in terms of real dollars:

- municipal tax payers pay for approximately 75 percent of municipal road construction costs; and

- drivers pay approximately 80 percent of provincial construction costs through gasoline taxes, registration and license fees, and traffic fines.

In 1993, Canadians spent over 10 billion dollars on roads, highways, and parking lots – 11 percent of the value of total construction work for that year.

Congestion

The debate about fixed links, bridges and highway expansions continually raises the issue of congestion, sparking the "if we build it, they will come" phenomenon. As soon as an expressway is completed, it is congested.

Congestion intensifies environmental problems associated with car travel, by increasing travel time and minimising fuel efficiency. The average speed of a morning commute in Vancouver decreased seven percent over the last ten years, but average travel time increased 20 percent.

The associated environmental costs of congestion are proportionally increased as well. Emissions increase during acceleration, deceleration and idling – conditions of stop-and-go traffic. Carbon dioxide emissions double when speeds drop from 55 to 30 km/hr, and hydrocarbon emissions triple at speeds less than 60 km/hr compared with a constant speed of 80 km/hr.

Future infrastructure

Building new and expanding existing infrastructure is becoming a hotly contested issue. Whether it be as national an issue as the fixed link to P.E.I. or as local as widening existing roads, the public is becoming increasingly aware of the impact of cars in society. All levels of government are beginning to examine closely these costs to plan for a sustainable transportation for the future.

Appendices

Glossary of Terms

Carbon Dioxide (CO_2): A gas naturally released by animals and decaying organisms, CO_2 is also absorbed and released by the ocean and by all plants during the growth cycle. After the industrial revolution, this natural cycle became unbalanced. CO_2 is the most significant greenhouse gas contributing to global warming.

Carbon Monoxide (CO): A colourless, odourless and tasteless gas produced through the incomplete combustion of organic materials. Fuel combustion is one of the main sources of CO, accounting for 37 percent of total emissions. Cars operating at colder temperatures (during winter or engine warmup) produce significant quantities of this poisonous gas. CO reduces the ability of the blood to carry oxygen; smokers, persons with heart disease, and those with anemia are especially sensitive. CO causes greater susceptibility to respiratory infections in children and the elderly. Additionally, release of CO into the atmosphere depletes the atmosphere's supply of OH (hydroxyl radical) which is the main natural cleansing agent of the atmosphere. As a result, CO emissions contribute to increases in methane, partially halogenated CFCs and the formation of ozone under certain NO_x conditions.

Hydrocarbons (including VOC): A numerous and chemically diverse group of compounds, non-methane hydrocarbons and volatile organic compounds (VOC) are important in the formation of ground-level ozone. VOC have at least one carbon atom and evaporate easily. Many individual VOC (e.g., benzene) are known to have or are suspected of having human health effects ranging from carcinogenicity to neurotoxicity. Some hydrocarbons from diesel emissions are carcinogenic. VOC contribute to the formation of ground-level ozone.

Nitrogen Oxides (NOx): Nitric Oxide (NO) is the major NO_x component and oxidises into nitrogen dioxide (NO_2) in the presence of hydrocarbons and sunlight. NO_2 reacts with hydrocarbons to form ozone, or with water to form nitrate (NO_3), a significant source of acid rain.

Nitrogen Dioxide (NO_2): A lung irritant which can produce pulmonary edema at high concentrations; increased susceptibility to respiratory infections in young children and the elderly; contributes to the corrosion of metals and degradation of textiles, rubber, and polyurethane; is associated with suppressed vegetation growth; contributes to ground-level ozone; and contributes to stratospheric ozone depletion.

Odour: Causes increased sensitivity of asthmatics and those suffering from bronchitis.

Ozone (O_3): Ozone is formed at ground level when NO_x and VOC combine in the presence of sunlight. It causes a decrease in lung function; eye irritation; decreased immune function; and plays a possible long-term role in development of chronic lung disease. Reduced agricultural productivity occurs in crops including soybeans, tomatoes, potatoes and corn; reduced growth rate in trees including red spruce, yellow pine and sugar maple. Ground-level ozone is also a global warming agent.

Suspended particulate matter: Suspended particulate are small particles of solid and liquid matter found mainly in diesel emissions. Small particles can penetrate lungs and cause respiratory infections, toxic particles can be taken into the bloodstream. Decreased visibility and aesthetic damage to buildings are other effects.

Abbreviations

CCME	Canadian Council of Ministers of the Environment
CEPA	*Canadian Environmental Protection Act*
CFC	Chlorofluorocarbon
CO	Carbon monoxide
CO_2	Carbon dioxide
ECP	Environmental Choice^M Program
EPA	Environmental Protection Agency (US)
ETBE	Ethyl tertiary butyl ether
GM	General Motors
g/km	Grams per kilometre
HBFC	Hydrobromofluorocarbon
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HDV	Heavy-duty vehicle
HFC	Hydrofluorocarbon
HOV	High occupancy vehicle
HSR	Hamilton Street Railway
I/M	Inspection and maintenance
IQUA	Index of the quality of air
kg	Kilogram
km/hr	kilometre per hour
LPG	Liquefied petroleum gasoline
LSD	Low-sulphur diesel
MCF	Methylchloroform
Micrograms/m^3	Micrograms per cubic metre
MOU	Memorandum of Understanding
MTBE	Methyl tertiary butyl ether
NAPS	National Air Pollution Surveillance
NMHC	Non-methane hydrocarbon
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NO_x	Nitrogen oxide
O_2	Oxygen molecule

O_3	Ozone
OEM	Original equipment manufacturer
PAH	Polycyclic aromatic hydrocarbon
ppb	Parts per billion
ppm	Parts per million
SOV	Single occupant vehicle
SO_2	Sulphur dioxide
SP	Suspended particulate
TDM	Transportation demand management
TSP	Total suspended particulate
TTC	Toronto Transit Commission
US	United States
UPS	United Parcel Service
UV-B	Ultraviolet-B rays
UV-C	Ultraviolet-C rays
VOC	Volatile organic compound

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